FNAL Emittance Devices

Flying Wires (FW)

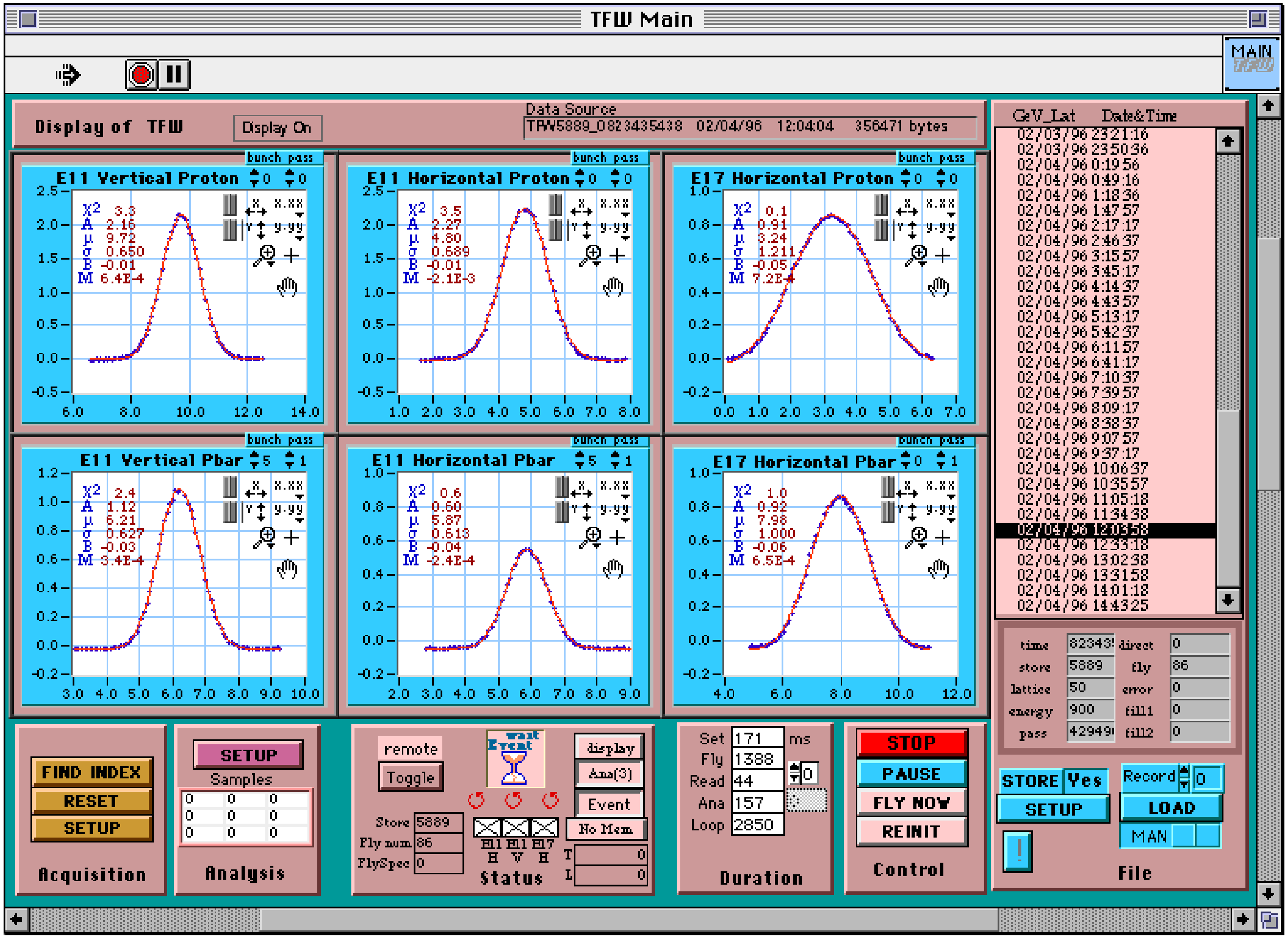
Sync Lite

Ion Profile Monitors (IPM)

aah,6/20/2000

Flying Wires

- Flying Wires are located in the Tevatron and Main Injector Accelerators.
- They represent the principle emittance measurment devices in the FNAL complex.
- Complex motion/measurement system, but once solved, provides very accurate and believable RMS measurements.
- Major uncertainties are in the position measurement and the linearity of the pickups (plastic scintillator-pmt assemblies).
  - Online examination of the motion allows smoothing, and other software interpolation, but up to now, the raw position data are good enough.
  - The linearity has been studied by comparing the areas of the profiles with measured beam intensities from other methods. They agree at the 5% level.
  - We are exploring the use of solid state pmt equivalents.
- 30 μm wire diameter contributes at most 7.5 μm (in quadrature) to measured beam rms profile, not significant for Tevatron beam sizes of ~0.5mm.

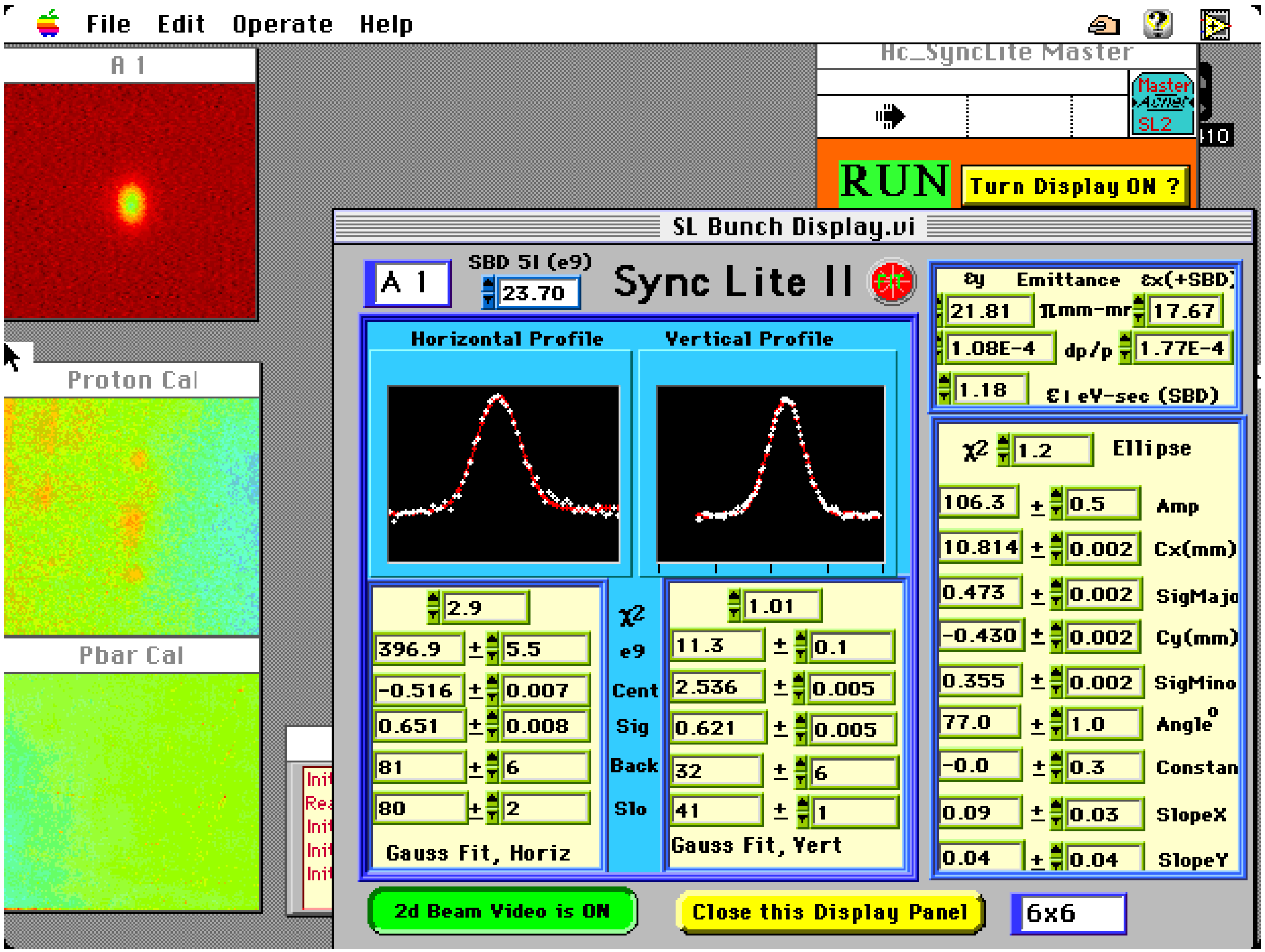


Flying Wire profiles (proton and antproton) at the three Tevatron FW cans. Horizontal E17 is a high dispersion region

Sync Lite

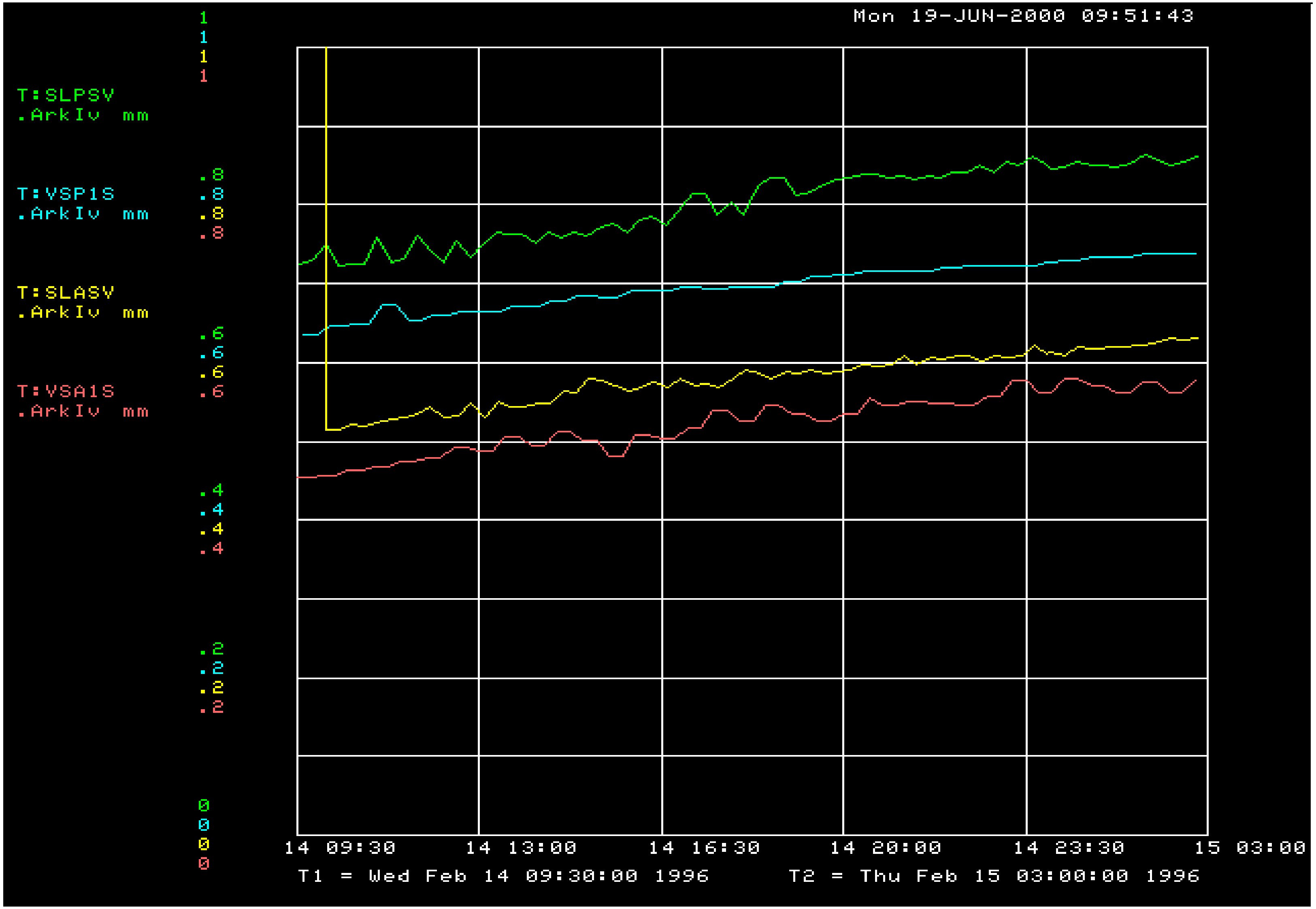
- Optics: We cannot setup in tunnel with external light source since the source region (edge of Tevatron Dipole) is in a Cryo region. So a lot of problems were related to poor optic configurations, which were only finally fixed (by trial and error) in the last few months of Run 1b (Jan-Feb 1996).
- Worries about gain saturation/sag in image intensifier (microchannel plate) led to measurements which show at most a ~5% effect when the light level was changed a factor of 2.
- Image Intensifier develops dead areas after long term exposure to bright beam spots. Tried to ameliorate by turning it on only during measurement and turning it off immediately after. Also implemented software gain correction based upon a gain map obtained by illuminating the image intensifier with a UV light (once a day). This map was used to make a pixel by pixel gain correction. (see the Proton Cal and Pbar Cal Windows on Sync Lite Picture on next slide). Especially note dark areas due to aging on Proton Cal image.

Image from Sync Lite (AntiProton Bunch 1) Note that ellipse fit is not enabled in this particular picture.



FW and Sync Lite Performance

- Datalog plot (saved every 15 minutes) from Feb. 1996. Actually FW sampled every 30 minutes, SL every 12 seconds. From Start of Store 5906 to end of Store. (Pbar mirror inserted after Low-Beta Squeeze, which is why it is off-scale at the beginning)
- Green (Yellow) = Proton(Pbar) RMS beam size from SyncLite
- Blue (Red)= Proton(Pbar) RMS beam size from Flying Wires.



Mon 19-JUN-2000 09:51:43
T:SLPSV
.ArkIv mm
T:VSP1S
.ArkIv mm
T:SLASV
.ArkIv mm
T:VSA1S
.ArkIv mm
1
.8
.6
.4
.2
0
14 09:30
14 13:00
14 16:30
14 20:00
14 23:30
15 03:00
T1 = Wed Feb 14 09:30:00 1996
T2 = Thu Feb 15 03:00:00 1996

Comparison FW to SL

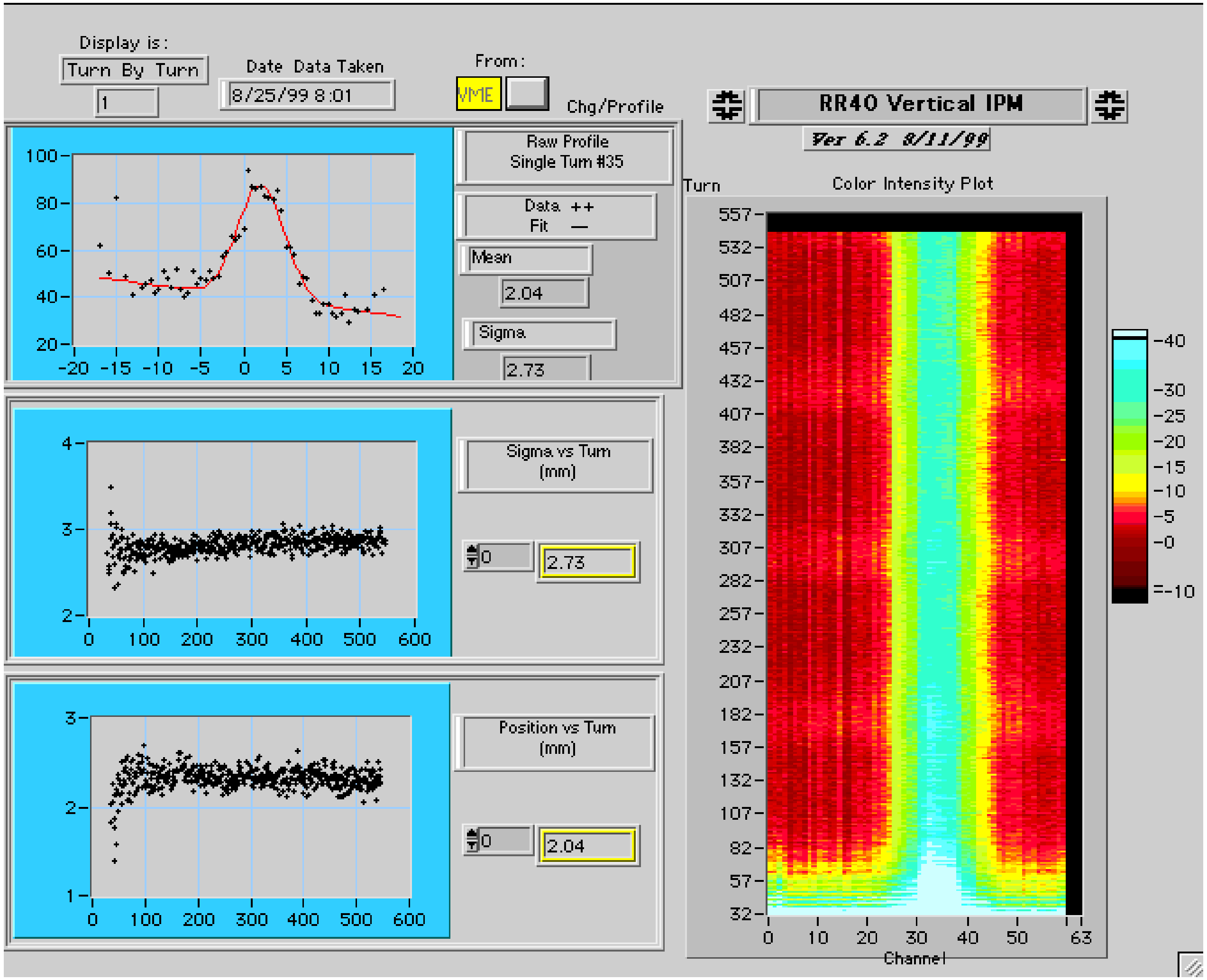
- The emittances were not archived, so in order to compare the RMS beam size, we need the scale factor between FW and SyncLite $= (\beta_{FW} / \beta_{SL})^{0.5}$
- The values are Proton (Pbar) = 0.85(0.88)
- Measured ratio Proton(Pbar) from previous slide = 0.88(0.89).
- They agree quite well (4% systematic)
- Statistical error/measurement also can be seen on the plot, roughly at the few % level.

Ion Profile Monitor (IPM)

- IPM's are installed in Booster (0.4->8GeV), Recycler (8GeV), Main Injector (8->150GeV), and are planned for Tevatron.
- The correction factor (due to space charge of beam) for narrow high intensity beams (>e12 and <3mm rms) are large (>50% and larger). We believe it makes sense to change over to e^- collection and place the entire assembly within a 2~3kG magnetic field. This should almost eliminate the corrections to values on the order of 10~20%.
- That being said, we have had very significant problems making precision absolute IPM measurements at the 2~3mm rms level. This brings up several electrical/mechanical issues:
  – Saturation of the microchannel plate gain stage of the IPM (or ePM). We have purchased and used "high" leakage current glass, which helps somewhat. We have not yet been able to calibrate the gain of the IPM (channel to channel variations and absolute gain). Beam bumping has provided some information concerning relative gains.
  – Suspicions that the IPM channel strips (0.5mm x 100 mm) are not parallel to the beam direction, thus broadening the measured beam rms size. We are planning to add an *in situ* motor alignment. The technique will be to adjust the relative angle of the strips to the beam, by minimizing the rms beam size.

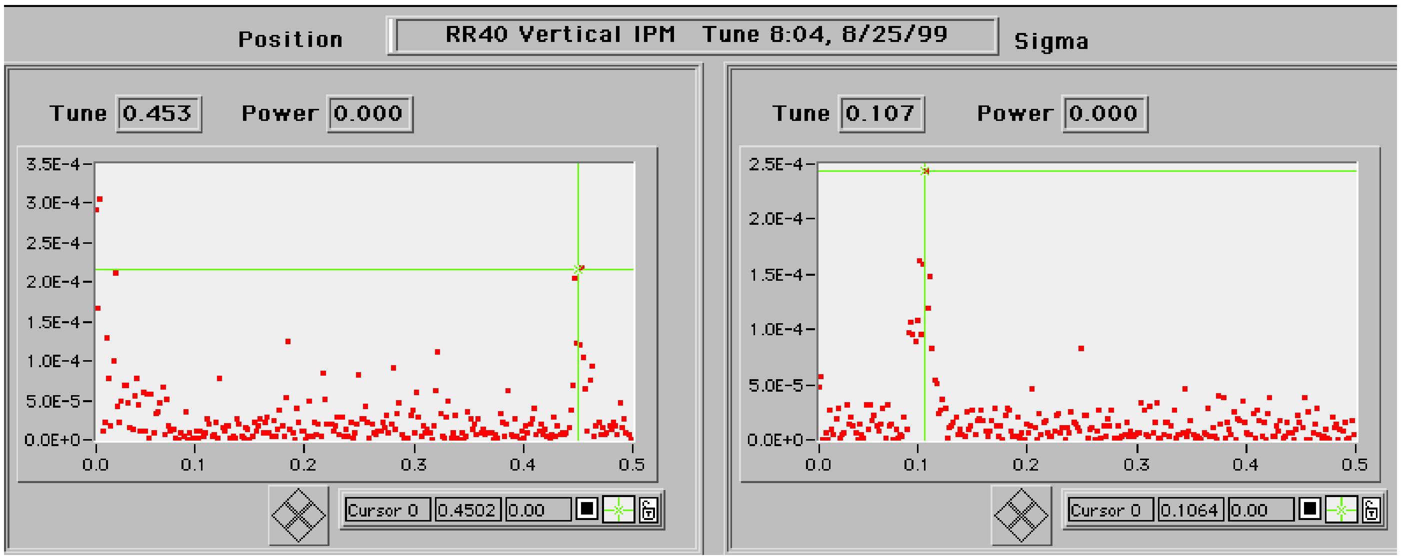
IPM Continued

- We run the IPM’s in turn by turn mode. The analog electronics provide some analog integration (~1 μs, roughly a Booster Batch).
- Their general utility up to now has been to monitor the beam at injection, where we look for relative changes in beam position and sigma.



First 512 turns of beam injected into FNAL Recycler. Two lower left plots show Sigma and Position of beam (in mm) vs turn #. Right Plot is false color mountain range plot of same 512 turns (injection is at bottom of plot. Upper left plot is data and fit of turn # 35 (very close to injection).

Shows capability of IPM in turn by turn mode to measure injection Beta wave when only relative beam sizes matter



FFT (in tune units) of first 512 turns of Position (left plot) and Sigma (RMS) from previous IPM Slide. Vertical tune =0.453. Peak at 0.107 in Sigma plot corresponds to (1-2*tune) of posititon plot, indicating a beta wave around the Recycler.

Comparison of FNALEmittance Monitors

	Flying Wires	Sync Lite	IPM
Image Type	Profile only	2d (3d?) image	Profile Only
Sampling	Bunch by Bunch	Bunch by Bunch	Batch
Directionality	Excellent	Excellent	Poor (timing only)
Beam Interaction	Interceptive	Non-Interceptive	Non-Interceptive
Daq Speed	fast to every 30 min	Continuous Cycling	On demand
Stability	OK	MCP Normalization	MCP degradation
Applicability	Pbar, MI, Tevatron	only works above 700GeV	Works everywhere
Linearity?	phototube nonlinearity	Nonlinearity of MCP	Nonlinearity of MCP
Profile Acquisition	Multiturn to acquire profile	Multiturn (currently)	Turn by turn
Ultimate Limit	Smoothness of motion	Diffraction (~0.2 mm)	Pickup width,
Requirements	room for scintillator	Need warm area after Dipole	Need magnets (ē mode)
Status	Working well NOW!	Working ok now	Needs work
Uncertainties?	Lattice	Lattice	Lattice

Color Coding ofTable : Green= Good Black= “OK” Red= needs work